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TITLE: Small Non-Reciprocal Circuit Element With Good Productivity

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SMALL NON-RECIPROCAL CIRCUIT ELEMENT WITH GOOD PRODUCTIVITY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to non-reciprocal circuit elements, such as circulators and isolators, to be applied to transmitting and receiving systems or the like.

2. Description of the Related Art

Figs. 13 and 14 show a known non-reciprocal circuit element. Specifically, Fig. 13 is an exploded perspective view of the known non-reciprocal circuit element, and Fig. 14 is a perspective view of a ferrite part of the known non-reciprocal circuit element.

Referring to Figs. 13 and 14, the structure of the known non-reciprocal circuit element will now be described. A base 51, which is a synthetic-resin molded part, includes a recess 51a disposed at the center and a plurality of notches 51b disposed on the top surface of the base 51.

Three chip capacitors C1, C2, and C3 and a chip resistor R are housed in the notches 51b.

First, second, and third central conductors 53, 54, and 55 formed of thin films are disposed on the top surface of a disc-shaped ferrite part 52.

The first, second, and third central conductors 53, 54, and 55 are stacked on one another with dielectric parts (which are not shown in these figures) formed of insulating thin films disposed therebetween. Portions of the first, second, and third central conductors 53, 54, and 55 intersect

at an angle of 120°.

The ferrite part 52 is housed in the recess 51a. One end of the first central conductor 53 is wire-bonded to the capacitor C1. One end of the second central conductor 54 is wire-bonded to the capacitor C2. One end of the third central conductor 55 is wire-bonded to the capacitor C3.

Two magnetic discs 56 are disposed above and below the ferrite part 52. On the top surface of the upper magnetic disc 56, a first yoke 57 is disposed. On the bottom surface of the lower magnetic disc 56, a second yoke 58 is disposed. The first and second yokes 57 and 58 are connected to form a magnetic closed circuit.

The above mentioned known non-reciprocal circuit element has the first, second, and third thin-film central conductors 53, 54, and 55 disposed only on the top surface of the ferrite part 52. To arrange the first, second, and third central conductors 53, 54, and 55 on the ferrite part 52, wires must be used. This is unfavorable in terms of productivity and cost.

Since the above mentioned known non-reciprocal circuit element requires the chip capacitors C1, C2, and C3 and the chip resistor R, it is cumbersome to assemble these parts in place. The size of the non-reciprocal circuit element becomes large.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a small inexpensive non-reciprocal circuit element

with good productivity.

To achieve the above mentioned object, according to an aspect of the present invention, a non-reciprocal circuit element is provided including a flat plate-shaped ferrite part; and first, second, and third central conductors disposed over a plurality of surfaces of the ferrite part, wherein the first, second, and third central conductors on a top surface of the ferrite part are stacked on one another with first dielectric parts disposed therebetween, and portions of the first, second, and third central conductors intersect vertically. The first, second, and third central conductors and the first dielectric parts are formed of multilayer thin films or thick films. Each of the first, second, and third central conductors includes a first extended portion which extends from one end of the corresponding central conductor and which is disposed on a side surface of the ferrite part and a second extended portion which extends from the other end of the corresponding central conductor and which is disposed on the side surface of the ferrite portion. The adjacent first and second extended portions facing each other with a second dielectric part, which is formed of a thin film or a thick film, disposed therebetween form a capacitor. With this arrangement, without using known chip capacitors, the capacitors are thinly formed, leading to reduction in size and cost of the non-reciprocal circuit element. Since the capacitors are formed between the central conductors, wiring, such as wire-bonding, becomes unnecessary. The non-

reciprocal circuit element thus becomes easy to assemble.

Each of the first and second extended portions may include a longitudinal extended segment extending downward from one end of the corresponding central conductor and a lateral extended segment extending orthogonally to the longitudinal extended segment. The lateral extended segments of the adjacent first and second extended portions may face each other with the second dielectric part disposed therebetween to form the capacitor. Accordingly, the side surface of the ferrite part is used effectively. The easy-adjustable capacitors with large capacitances and good capacitance accuracy are achieved.

A first capacitor may be formed between the first and third central conductors, a second capacitor may be formed between the first and second central conductors, and a third capacitor may be formed between the second and third central conductors. Accordingly, the small non-reciprocal circuit element, which is suitably applied to a circulator, is achieved.

A resistor formed of a thin film or a thick film may be disposed on the side surface of the ferrite part, and the resistor may be connected between the second extended portion of the first central conductor and the first extended portion of the third central conductor. Accordingly, without using a known chip resistor, the resistor is thinly formed. The small non-reciprocal circuit element, which is suitably applied to an isolator, is achieved.

The first and second extended portions may include first

and second terminal portions, respectively, which are disposed on a bottom surface of the ferrite part, each first terminal portion extending from one end of the corresponding first extended portion, and each second terminal portion extending from one end of the corresponding second extended portion. Accordingly, the central conductors are easily connected to other parts, such as a circuit board or an insulated board. The non-reciprocal circuit element thus becomes easy to assemble.

The second terminal portions may be connected to one another by a connecting conductor disposed on the bottom surface of the ferrite part. Accordingly, the second terminal portions to be grounded are reliably connected at the same time.

The non-reciprocal circuit element may further include first and second yokes connected to each other to form a magnetic closed circuit; a magnet disposed on the ferrite part; and a circuit board having first and second conductive patterns and holes. The bottom surface of the ferrite part may be placed on the circuit board. The first terminal portions may be connected respectively to the first conductive patterns, and the second terminal portions may be connected to the second conductive pattern. The first yoke may be disposed on the top surface of the ferrite part, and the second yoke may be disposed on a bottom surface of the circuit board. One or both of the first and second yokes may be disposed inside the holes, thereby connecting the first and second yokes with each other. With this arrangement, the

non-reciprocal circuit element is directly embedded in the circuit board. The non-reciprocal circuit element thus becomes compact and easy to assemble.

The non-reciprocal circuit element may further include first and second yokes connected to each other to form a magnetic closed circuit; a magnet disposed on the ferrite part; and an insulated board having first and second leader terminals. The bottom surface of the ferrite part may be placed on the insulated board. The first terminal portions may be connected respectively to the first leader terminals, and the second terminal portions may be connected to the second leader terminal. The first yoke may be disposed on the top surface of the ferrite part, and the second yoke may be disposed on a bottom surface of the insulated board, thereby connecting the first and second yokes with each other. With this arrangement, the small non-reciprocal circuit element alone is easily manufactured.

According to another aspect of the present invention, a non-reciprocal circuit element is provided including a flat plate-shaped ferrite part; and first, second, and third central conductors disposed over a plurality of surfaces of the ferrite part, wherein the first, second, and third central conductors on a top surface of the ferrite part are stacked on one another with first dielectric parts disposed therebetween, and portions of the first, second, and third central conductors intersect vertically. The first, second, and third central conductors and the first dielectric parts are formed of multilayer thin films or thick films. Each of

the first, second, and third central conductors includes a first extended portion which extends from one end of the corresponding central conductor and which is disposed on a side surface of the ferrite part; a second extended portion which extends from the other end of the corresponding central conductor and which is disposed on the side surface of the ferrite portion; a first terminal portion which extends from one end of the corresponding first extended portion and which is disposed on a bottom surface of the ferrite part; and a second terminal portion which extends from one end of the corresponding second extended portion and which is disposed on the bottom surface of the ferrite part. Accordingly, the central conductors are easily connected to other parts, such as a circuit board or an insulated board. The non-reciprocal circuit element thus becomes easy to assemble.

The second terminal portions may be connected to one another by a connecting conductor disposed on the bottom surface of the ferrite part. Accordingly, the second terminal portions to be grounded are reliably connected at the same time.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an elevation view of a non-reciprocal circuit element, which is applied to a circulator, according to a first embodiment of the present invention;

Fig. 2 is a plan view of a circuit board of the circulator shown in Fig. 1;

Fig. 3 is a perspective view of a ferrite part of the

circulator shown in Fig. 1;

Fig. 4 is a perspective view of the ferrite part of the circulator shown in Fig. 1, which is viewed from the backside;

Fig. 5 is a three-dimensional wiring diagram of the circulator shown in Fig. 1;

Fig. 6 is a circuit diagram of the circulator shown in Fig. 1;

Fig. 7 is an elevation view of a non-reciprocal circuit element, which is applied to an isolator, according to a second embodiment of the present invention;

Fig. 8 is a plan view of an insulated board of the isolator shown in Fig. 7;

Fig. 9 is a perspective view of a ferrite part of the isolator shown in Fig. 7;

Fig. 10 is a perspective view of the ferrite part of the isolator shown in Fig. 7, which is viewed from the backside;

Fig. 11 is a three-dimensional wiring diagram of the isolator shown in Fig. 7;

Fig. 12 is a circuit diagram of the isolator shown in Fig. 7;

Fig. 13 is an exploded perspective view of a known non-reciprocal circuit element; and

Fig. 14 is a perspective view of a ferrite part of the known non-reciprocal circuit element shown in Fig. 13.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The drawings of a non-reciprocal circuit element

according to the present invention will now be described. Fig. 1 is an elevation view of a non-reciprocal circuit element, which is applied to a circulator, according to a first embodiment of the present invention. Fig. 2 is a plan view of a circuit board of the circulator shown in Fig. 1. Fig. 3 is a perspective view of a ferrite part of the circulator shown in Fig. 1. Fig. 4 is a perspective view of the ferrite part of the circulator shown in Fig. 1, which is viewed from the backside. Fig. 5 is a three-dimensional wiring diagram of the circulator shown in Fig. 1. Fig. 6 is a circuit diagram of the circulator shown in Fig. 1.

Fig. 7 is an elevation view of a non-reciprocal circuit element, which is applied to an isolator, according to a second embodiment of the present invention. Fig. 8 is a plan view of an insulated board of the isolator shown in Fig. 7. Fig. 9 is a perspective view of a ferrite part of the isolator shown in Fig. 7. Fig. 10 is a perspective view of the ferrite part of the isolator shown in Fig. 7, which is viewed from the backside. Fig. 11 is a three-dimensional wiring diagram of the isolator shown in Fig. 7. Fig. 12 is a circuit diagram of the isolator shown in Fig. 7.

Referring to Figs. 1 to 6, the structure of the non-reciprocal circuit element, which is the circulator, according to the first embodiment of the present invention will now be described. With particular reference to Fig. 2, a circuit board 1, which is a printed circuit board, includes a plurality of arc-shaped holes 1a. On the top surface of the circuit board 1, a plurality of first conductive patterns

2 with land portions 2a are disposed at equal distances around a second conductive pattern 3 with a land portion 3a.

The first and second conductive patterns 2 and 3 are connected to a transmitting and receiving circuit disposed on the circuit board 1. The second conductive pattern 3 is used for grounding.

The land portions 2a and 3a are housed in the holes 1a.

On a ferrite part 4, which is a YIG (Yttrium iron garnet) flat plate (which is disc-shaped), first, second, and third central conductors 5, 6, and 7, which are formed of thin films or thick films, are disposed over a top surface 4a, a side surface 4b, and a bottom surface 4c.

The first, second, and third central conductors 5, 6, and 7 disposed on the top surface 4a of the ferrite part 4 are stacked on one another via first dielectric parts (not shown), which are formed of insulating thin films or insulating thick films, disposed therebetween. The first, second, and third central conductors 5, 6, and 7 are disposed at equal distances at an angle of 120°. Portions of the first, second, and third central conductors 5, 6, and 7 intersect vertically.

To form the first, second, and third central conductors 5, 6, and 7 using thin films, chromium (Cr), copper (Cu), and the like are deposited by evaporation. To form the first, second, and third central conductors 5, 6, and 7 using thick films, a silver (Ag) paste and a copper (Cu) paste are printed.

To form the first insulating parts (not shown) for

insulating between the first, second, and third central conductors 5, 6, and 7 using thin films, silicon oxide and the like are deposited by evaporation. To form the first insulating parts using thick films, palladium titanate and the like are printed.

Each of the first, second, and third central conductors 5, 6, and 7 includes a first extended portion 8 which extends from one end of the corresponding central conductor and which is disposed on the side surface 4b of the ferrite part 4 and a second extended portion 9 which extends from the other end of the corresponding central conductor and which is disposed on the side surface 4b of the ferrite part 4.

Each first extended portion 8 includes a longitudinal extended segment 8a extending downward from the top surface and a lateral extended segment 8b extending orthogonally to the longitudinal extended segment 8a. The second extended portion 9 includes a longitudinal extended segment 9a extending downward from the top surface and a lateral extended segment 9b extending orthogonally to the longitudinal extended segment 9a.

The first and second extended portions 8 and 9 of the first, second, and third central conductors 5, 6, and 7 include first and second terminal portions 10 and 11, respectively. Each first terminal portion 10 extends from one end of the corresponding first extended portion 8 and is disposed on the bottom surface 4c of the ferrite part 4, and each second terminal portions 11 extends from one end of the corresponding second extended portion 9 and is disposed on

the bottom surface 4c of the ferrite part 4. The second terminal portions 11 are connected with one another by a connecting conductor 12 disposed on the bottom surface 4c of the ferrite part 4.

The lateral extended segment 8b of the first extended portion 8 of the first central conductor 5 faces the lateral extended segment 9b of the second extended portion 9 of the third central conductor 7 with a second dielectric part (not shown) formed of an insulating thin film or an insulating thick film disposed therebetween, thereby forming a first capacitor C1 between the adjacent first and second extended portions 8 and 9.

The lateral extended segment 9b of the second extended portion 9 of the first central conductor 5 faces the lateral extended segment 8b of the first extended portion 8 of the second central conductor 6 with a second dielectric part (not shown) formed of an insulating thin film or an insulating thick film disposed therebetween, thereby forming a second capacitor C2 between the adjacent first and second extended portions 8 and 9.

The lateral extended segment 9b of the second extended portion 9 of the second central conductor 6 faces the lateral extended segment 8b of the first extended portion 8 of the third central conductor 7 with a second dielectric part (not shown) formed of an insulating thin film or an insulating thick film disposed therebetween, thereby forming a third capacitor C3 between the adjacent first and second extended portions 8 and 9.

As a result, the first, second, and third capacitors C1, C2, and C3 are wired, as shown in Fig. 5.

To form the second dielectric parts insulating between the first and second extended portions 8 and 9 using thin films, as in the first dielectric parts, silicon oxide and the like are deposited by evaporation. To form the second dielectric parts using thick films, palladium titanate and the like are printed.

The capacitance of each capacitor can be adjusted by trimming the upper one of the corresponding lateral extended segments.

The bottom surface 4c of the ferrite part 4 arranged as described above is placed on the circuit board 1. Each of the first terminal portions 10 is connected by soldering to the land portion 2a of the corresponding first conductive pattern 2. The connecting conductor 12, which is electrically connected to the second terminal portions 11, is connected by soldering to the land portion 3a of the second conductive pattern 3. As a result, the second terminal portions 11 are grounded.

A first yoke 13, which is a magnetic plate (steel plate or the like), is U-shaped and includes a top plate 13a and side plates 13b extending downward from two facing sides of the top plate 13a. On the inner side of the top plate 13a, a magnetic bar 14 is disposed.

The magnetic bar 14 is disposed above the ferrite part 4. Lower end portions of the side plates 13b are disposed inside the holes 1a.

A second yoke 15, which is a U-shaped magnetic plate (steel plate or the like), includes a quadrilateral bottom plate 15a and a pair of side plates 15b extending upward from two facing sides of the bottom plate 15a.

While the second yoke 15 is disposed on the bottom surface of circuit board 1, upper end portions of the side plates 15b are disposed inside the holes 1a. Therefore, the first and second yokes 13 and 15 are connected to each other.

As a result, the first and second yokes 13 and 15 form a magnetic closed circuit.

Referring to Figs. 4 and 6, the first terminal portions 10 of the first, second, and third central conductors 5, 6, and 7 are grounded via the first, second, and third capacitors C1, C2, and C3. The second terminal portions 11 are grounded.

Although the capacitors are provided in the first embodiment, the capacitors may not be provided.

Although the first and second yokes 13 and 15 are disposed inside the holes 1a, only one of the first and second yokes 13 and 15 may be disposed inside the holes 1a.

Figs. 7 to 12 show a case in which a non-reciprocal circuit element according to a second embodiment of the present invention is applied to an isolator. A first difference between the first and second embodiments is that a resistor 16 is additionally disposed, as particularly shown in Figs. 9 and 10.

The resistor 16, which is formed of a thin film or a thick film, is disposed on the side surface 4b of the ferrite

part 4. To form the resistor 16 using a thin film, tantalum and silicon oxide are deposited by evaporation. To form the resistor 16 using a thick film, a resistive material consisting of a mixture of carbon and an organic binder or the like is printed.

The resistor 16 is connected to the second extended portion 9 of the first central conductor 5 and to the first extended portion 8 of the third central conductor 7.

A second difference between the first and second embodiments is that, instead of using the circuit substrate 1, an insulated board 17 is used in the second embodiment. With particular reference to Fig. 8, the insulated board 17 includes first leader terminals 18 disposed at equal distances at an angle of 120° and a second leader terminal 19 arranged between the first leader terminals 18.

Each of the first leader terminals 18 consists of a land portion 18a formed of a conductive pattern and a terminal strip 18b which is electrically connected to the land portion 18a and which is mounted on the insulated board 17. The second leader terminal 19 consists of a land portion 19a formed of a conductive pattern and terminal strips 19b which are electrically connected to the land portion 19a and which are mounted on the insulated board 17.

The bottom surface 4c of the ferrite part 4 is placed on the insulated board 17. The first terminal portions 10 are respectively connected by soldering to the land portions 18a of the first leader terminals 18. The connecting conductor 12, which is electrically connected to the second terminal

portions 11, is connected by soldering to the land portion 19a of the second leader terminal 19, and hence the second terminal portions 11 are grounded.

Alternatively, the first and second leader terminals 18 and 19 may be formed by embedding terminals formed of metal plates in the insulated board 17, so that these terminals may serve both as the land portions 18a and 19a and the terminal strips 18b and 19b.

Since the other structure of the second embodiment is the same as that of the first embodiment, the same reference numeral is given to the same part, and a repeated description thereof is omitted.

Referring to Figs. 11 and 12 showing the isolator arranged as described above according to the second embodiment, the first terminal portions 10 of the first and second central conductors 5 and 6 are grounded via the first and second capacitors C1 and C2; the second terminal portions 11 of the first and second central conductors 5 and 6 are grounded; the first terminal portion 10 of the third central conductor 7 is grounded via the third capacitor C3 and the resistor R; and the second terminal portion 11 of the third central conductor 7 is grounded.

Although the capacitors and the resistors are disposed in the second embodiment, the capacitors and the resistors may not be disposed.

The circuit board 1 of the first embodiment may be replaced by the insulated board 17 of the second embodiment. The insulated board 17 of the second embodiment may be

replaced by the circuit board 1 of the first embodiment.